

## A NEW FUNGUS OF ECONOMIC IMPORTANCE.

RALPH E. SMITH AND ELIZABETH H. SMITH.

(WITH THREE FIGURES)

AMONG the subjects of investigation by the California Agricultural Experiment Station, that of a destructive rotting of lemons occurring in southern California is one of the most important. The cause and means of control of this rot have been a complete mystery to the handlers of lemons, and the fact that the trouble has been found to be due to a fungus representing not only a new species, but a well-defined new genus, makes the case one of peculiar interest.

The rot in question has been called the "brown rot," distinguishing it from the "blue mould," or *Penicillium* rot, the commonest form of Citrus decay. The latter has been known since time immemorial, but with the best class of lemon shippers is not usually a great pest. Lemons affected by *Penicillium* are almost invariably those which have become bruised in handling or subjected to improper conditions. With fruit properly handled, cases of blue mould are only occasional. In these the affected lemon decays and becomes covered with the dusty fungus, finally collapsing into a slimy mass, without infecting the other fruit, even though they be covered with the spores. A *Penicillium*-affected lemon in the midst of a box does not usually infect the other fruit about it in the least when proper conditions are maintained.

Within the past few years a new and much more serious form of rot has been detected by the lemon growers and shippers. In lemons which had been picked, washed, and stored for curing, it was found that a rot developed which spread rapidly by contact through the fruit, soon involving the entire box if left undisturbed. In appearance the affected lemons are characteristic and easily distinguished from those affected by blue mould, though the latter fungus follows rapidly on the other and soon covers the decaying fruit. Particularly characteristic is the odor of lemons affected by brown rot, a peculiar rancid smell by which an experienced person can detect one affected lemon in a large amount of fruit. This



odor has, in fact, come to be the infallible test for brown rot in the lemon curing houses, readily distinguishing the trouble from all other forms of decay. The rapid spread in the box by contact, and the appearance of affected fruit, are also very characteristic, though the latter is soon disguised by *Penicillium*, and the former feature is even more true with a rot caused by *Sclerotinia*.

When brown rot first appeared in the packing houses, search was made in the orchard to locate the origin of the trouble, with the result that even upon the tree affected lemons could be found. This was only the case during the wet season, which, in fact, is the only time when the rot is troublesome.

It is not the purpose of the present article to describe this trouble at length, but simply to place on record a description of the fungus and sufficient characterization of its effects to serve to identify this form of lemon decay. Lemons affected on the tree show a brownish, discolored area on the side or end, free from any mould or appearance of fungus, and without any decided softening of the rind, but gradually spreading and soon involving the whole lemon. The fruit keeps its size, shape, and solidity, even when totally affected, before which time it usually drops to the ground. The orchard occurrence is not generally abundant except in wet, warm spring weather or under like conditions. Affected lemons have a peculiar characteristic odor, and are readily identified by one familiar with the disease.

Lemons are usually picked quite green, washed in a machine consisting of a tank of water with revolving brushes, and then stored in boxes for several weeks to cure. At times of abundant prevalence of rot, great loss is experienced in such stored fruit. In lemons apparently sound when put away, affected spots develop on individuals here and there in the boxes. These are soon involved, and also all those which lie in contact with them. These again spread the trouble, and an extremely virulent decay results. Lemons affected in this way have the appearance above described, except that a rather delicate, white mycelium develops on the surface and grows from lemon to lemon, causing the contact infection. The trouble never spreads in the mass of stored fruit except by actual contact of the healthy lemon with an affected spot. When a large



amount of fruit becomes affected the characteristic odor is very pronounced. *Penicillium* follows rapidly and covers the affected lemons.

With reference particularly to the cause of the trouble, the fungus, which comes out on affected fruit in moist air and spreads from

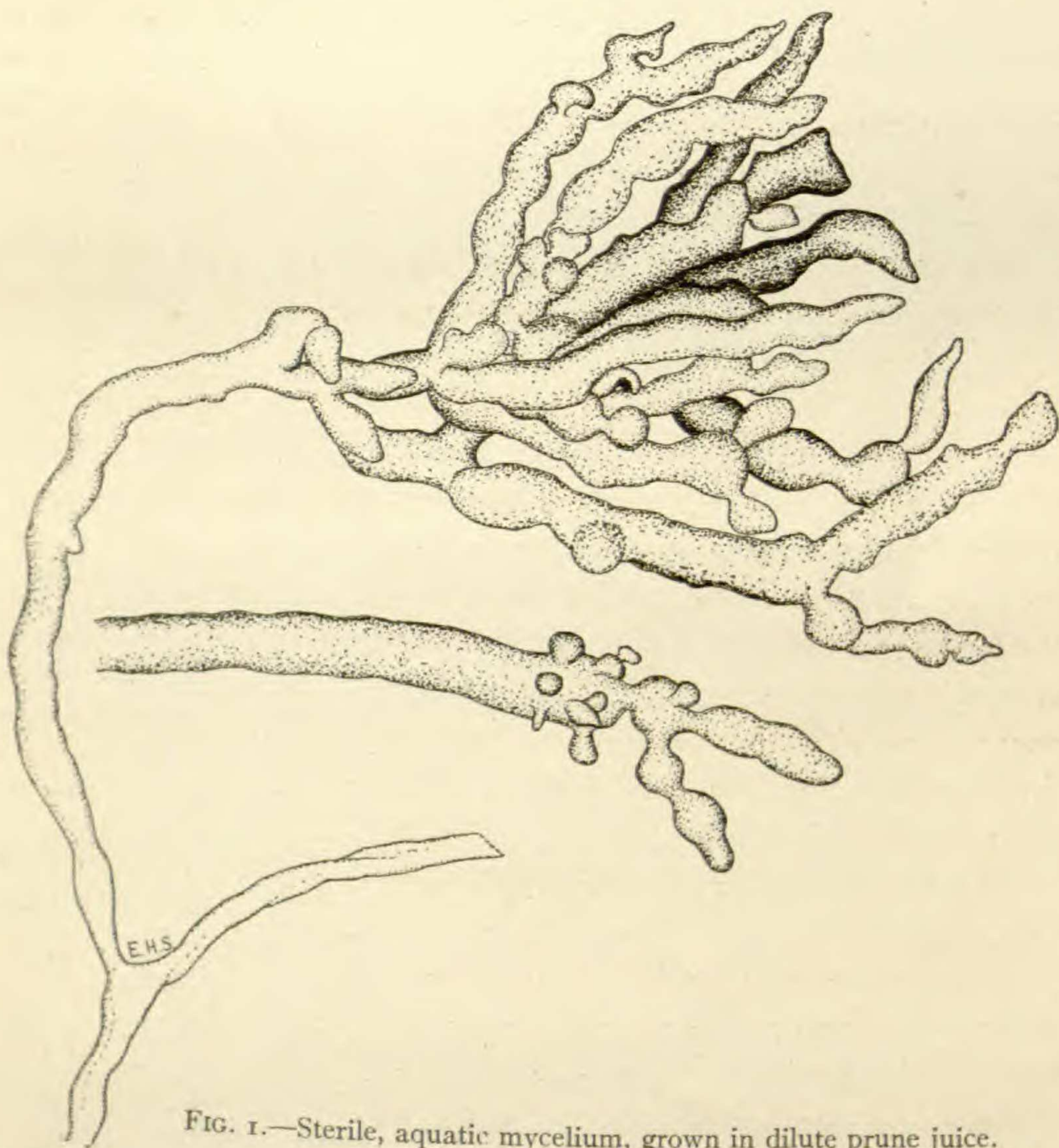
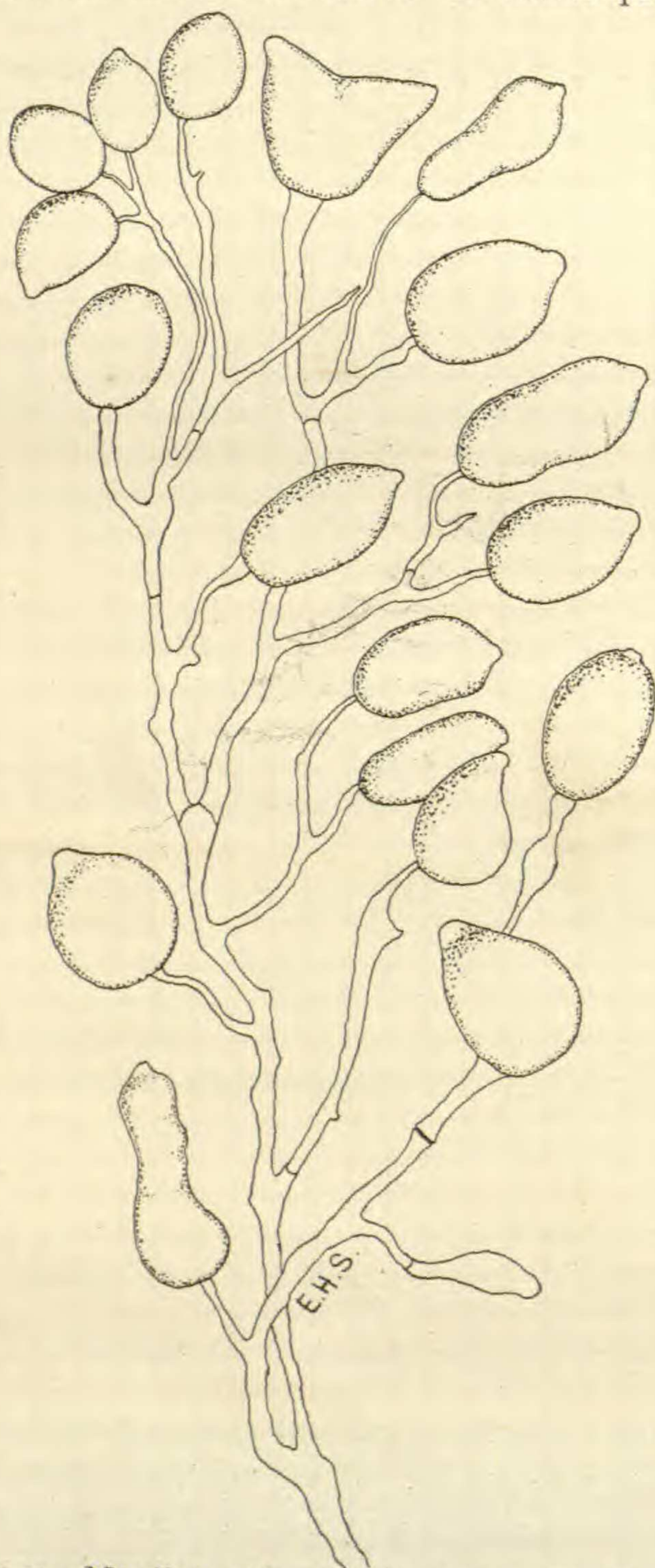


FIG. 1.—Sterile, aquatic mycelium, grown in dilute prune juice.

lemon to lemon, consists of a sterile mycelium, composed of large branching, mostly continuous filaments. If an affected lemon be placed in water for several hours, this mycelium develops more richly upon the surface, forming a slimy, *Saprolegnia*-like growth. The fungus quickly reaches the fibrous core of the lemon, bits of which soaked in water are soon surrounded with a luxuriant growth



On dry or simply moist media (gelatin, bread, etc.) little or no growth can be obtained. In dilute prune juice the fungus grows



with extreme vigor, forming a luxuriant mycelium of very large, branching, continuous filaments (*fig. 1*). Such growths are entirely sterile or nearly so. Occasionally there are produced a few large, ovate, terminal conidia or sporangia, of the phycomycete type, which germinate directly in water or form swarm-spores. Numerous cultures in various liquid media have developed nothing but the mycelium and occasional spores of this kind. This fungus is nearly sterile under such conditions, and entirely so on affected lemons in the air, though with extreme vegetative vigor. Cultures of pieces of affected lemon in pure water, kept for a long time, usually develop nothing but mycelium, though occasionally conidia or sporangia are produced to some extent.

**FIG. 2.**—Mycelium with sporangia, from moist soil. Bits of this sterile mycelium placed on sound lemons in a moist chamber produce infection and characteristic rot. Lemons soaked in water, into



which a sterile culture of the fungus has been mixed, also become infected.

Affected lemons placed on moist soil (as in nature by falling from the tree) produce a visible mycelium upon the surface and make such ground highly infectious to sound fruit laid upon the surface. In soil thus inoculated the characteristic spore stage of the fungus has been found. This is also readily produced on wet filter paper

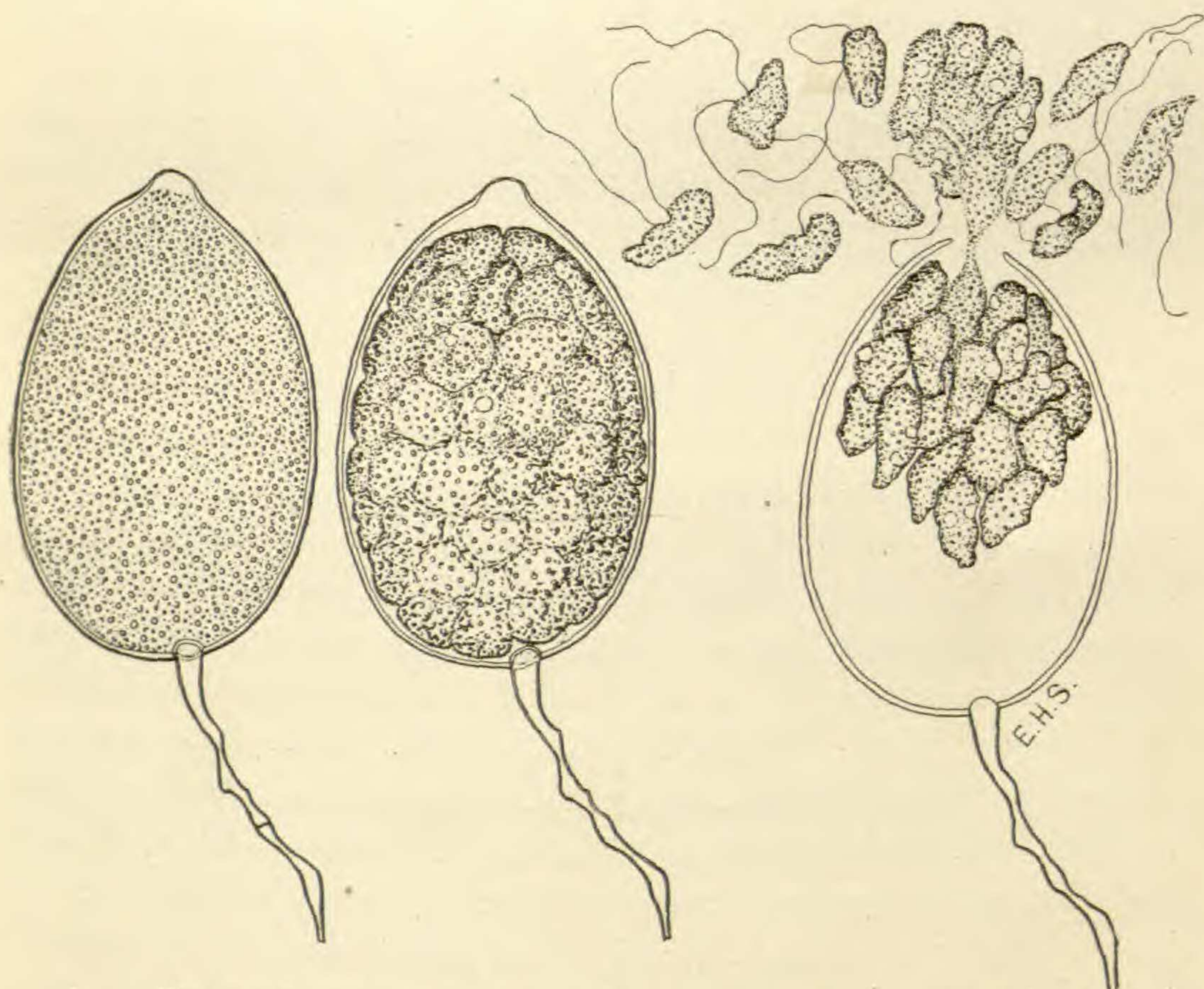


FIG. 3.—Stages in development of swarmspores from sporangia.

in the bottom of a moist chamber containing an affected lemon. Upon an extremely delicate, fine, septate, branching mycelium, very numerous, terminal sporangia are produced (*fig. 2*), much as in *Pythium* under similar conditions. These sporangia differ, however, from those of the latter genus, in producing swarmspores by direct internal division, behaving in this respect like those of *Phytophthora*, which they also resemble in appearance (*fig. 3*). The appended description gives further details. These swarm-



spores are extremely infectious to sound, green fruit in all stages of development.

Lemons on the tree become infected during the rainy winter and spring months, almost entirely on the lower part of the trees (which are allowed to branch close to the ground), and in the wettest part of the orchard. The fungus at all times shows a very decided moisture requirement for its development. Infection takes place by swarmspores from the soil, both on the tree and in the washing tank, in the latter case by the orchard dirt, dust, leaves, and other sediment which accumulates in the water.

The writers have given much consideration to the generic relations of this fungus, particularly as to whether it is sufficiently distinct from *Pythium* and from DE BARY's *Pythiopsis*. It is remarkable for the connection which it presents between the *Phycomycetes* of this nature. While similar to *Pythium* in habit, except as to its peculiar parasitism on the lemon, this species is definitely excluded from that genus by its internal formation of swarmspores. We have felt considerable hesitancy in separating this form from *Pythiopsis*, on account of the similarity in swarmspore formation; the latter, however, being founded on a species of such different habit, an entomophthorous form of the *Saprolegnieae*, and being practically unknown save from the original description, we feel justified in proposing a new genus for our species. It is particularly of interest as being more exactly intermediate between the *Saprolegnieae* and *Peronosporae* than either *Pythium* or *Pythiopsis*, and also forming a close transition from *Pythium* to *Phytophthora*, having the swarmspore formation and something of the parasitic tendency of the latter. In brief, *Pythiacystis* has the soil habit of *Pythium*, the aquatic habit of the same and of the *Saprolegnieae* (including *Pythiopsis*) except for its usual sterility under such conditions, the sporangia formation of *Pythium*, the swarmspore formation of *Pythiopsis* and *Phytophthora*, and parasitic activity intermediate between *Pythium* and *Phytophthora*.

No indication of sexual reproduction has been observed in the large amount of material and numerous cultures examined.

An Experiment Station bulletin on the nature and control of this fungus will be issued in due time.



**Pythiacystis** Smith & Smith, n. gen.

Parasitic on living plants, or saprophytic with abundant moisture. Fertile mycelium delicate, septate, with numerous, terminal, sympodially developed sporangia. Aquatic mycelium typically sterile, with occasional conidia or sporangia. Filaments very large and vigorous, continuous, much branched.

Sporangia typically rounded or ovate, dividing internally into biciliate swarmspores which immediately become motile and emerge from a terminal opening.

Conidia similar to sporangia, germinating directly by a germ tube.

Sexual reproduction not observed.

Differs from *Pythium* in mode of swarmspore formation, and from *Pythiopsis* in habit. Closely intermediate between *Saprolegnieae* and *Peronosporae*.

***Pythiacystis citrophthora*** Smith & Smith, n. sp.—Parasitic on lemons, and occasionally other Citrus fruits, causing decay of green fruit on the tree and in the storehouse. Mycelium in affected fruit sterile, inhabiting rind and fibrous portions. Internal, except in moist air. Mycelium in water or nutrient liquids very vigorous, usually sterile, or occasionally with conidia or sporangia. Fruiting stage found typically in moist soil, in contact with affected fruit. Sporangia ovate or lemon-shaped, sometimes rounded, considerably elongated, or double, with terminal protuberance;  $20 \times 30 \mu$  to  $60 \times 90 \mu$ , av.  $35 \times 50 \mu$ . Produced in great abundance under favorable conditions. In water dividing quickly by internal division into 5 to 40 (usually about 30) swarmspores, which are immediately set free and discharged through a terminal pore.

Swarmspores 10 to  $16 \mu$  in diameter, at first elongated, becoming rounded; with two lateral cilia 30 to  $40 \mu$  in length. Actively motile when discharged, soon coming to rest and germinating.

Fungus abundant in winter and spring in southern California lemon orchards and packing houses, causing serious losses.

UNIVERSITY OF CALIFORNIA, BERKELEY.